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Hydrothermal Reactions of Tricalcium Aluminate and Its Hydrates.

A STUDY has been made by the Department of Chemistry at the University of Saskatchewan, Saskatoon, Canada, of the hydrothermal reactions of tricalcium aluminate and its hydrates between 120 and 350 deg. C., and the results are reported by Messrs. G. M. Harris, W. G. Schneider, and T. Thorvaldson in the *Canadian Journal of Research* (April, 1943), published by the National Research Council, Ottawa.

The report states that precast concrete products when subjected to steam-curing normally contain an excess of water, and the condition for the formation of birefringent hydroaluminates of calcium are therefore present. The same applies to the commercial steam-curing of other materials containing free lime and hydrated alumina. The formation of these hydroaluminates may explain the peculiar effect on the tensile and compressive strength of mortar and concrete test pieces produced by hydrothermal treatment at temperatures above 150 deg. C. It is generally considered that the isometric hexahydrate of tricalcium aluminate is the most stable hydroaluminate of calcium in contact with saturated water vapour at and above room temperature. Under these conditions the hexagonal hydrates of tricalcium aluminate appear to be metastable with respect to the hexahydrate, although no transition point has been discovered. According to Lafuma, hydrated dicalcium aluminate when heated in contact with its mother liquor at 30 deg. C. changes to this stable product. It is also one of the products of the hydration of Portland cement

Tricalcium aluminate hexahydrate has been usually prepared by the direct hydration of the pure aluminate in saturated steam at 150 deg. C. Other workers have not found this method entirely satisfactory for obtaining a pure product, reporting the presence of an anisotropic impurity. Workers in the Saskatoon

laboratory have also observed this, particularly if the anhydrous aluminate contains a slight excess of alumina (in the form of the next aluminate lower in lime), but also at times when pure tricalcium aluminate had been used. The present paper reports a study of the hydrothermal behaviour of tricalcium aluminate and of its hexagonal and isometric hydrates.

The hydrothermal treatments were carried out as follows. The samples, contained in platinum crucibles, were supported above water in silver-lined, air-tight steel tubes heated at 120 deg. C. in an air oven. In some cases this arrangement was used at higher temperatures, the closed tubes being heated in an autoclave containing water. At 150 deg. C. an electrically-heated autoclave of hammered copper was used, the platinum crucible containing the aluminate being protected by a brass container perforated near its base. At higher temperatures the crucibles were suspended from the plunger of an electrically-heated steel bomb. The amount of water used was such that the crucibles were in all cases surrounded by the vapour phase. By means of auxiliary heating, the temperature of the bomb could be raised from room temperature to the maximum in from 5 to 30 minutes. The hydrothermal behaviour of the following was studied.

Preparation of Tricalcium Aluminate and Its Hydrates.

A series of five preparations of the hexahydrate, starting with the anhydrous aluminate, gave, on five to nine days' treatment in saturated steam at 120 deg. C. with subsequent drying *in vacuo* over lime, products containing from 5·98 to 6·00 moles of water per mole of the aluminate. Seven similar preparations carried out at 150 deg. C. gave, after 7-day to 14-day treatments, products containing from 5·98 to 6·01 moles of water. None of these samples showed any birefringent material under the microscope. In no case was there evidence of any appreciable condensation of water in the protected crucible containing the aluminate.

The hexagonal hydrate of tricalcium aluminate was prepared as follows. The anhydrous tricalcium aluminate was added gradually to distilled water containing pure ice. The heat of hydration was thus absorbed as latent heat of fusion and the temperature of the mixture remained at freezing point. The mass, contained in a closed gold-lined tube, was kept at this temperature, with frequent shaking, for two or three weeks and then dried at 21 deg. C. in evacuated desiccators over saturated solutions of lead nitrate (98 per cent. humidity), potassium acetate (21 per cent. humidity), and anhydrous magnesium perchlorate. The observed results varied somewhat with the size of the batch. Stored over lead nitrate, the samples appeared dry in four to six days, when the aluminate still held approximately 18 moles of water. This fell to about 14 moles in 6 to 10 days and then decreased very slowly to somewhat more than 12 moles in 30 to 40 days. The saturated solution of potassium acetate reduced the water held by the aluminate to somewhat more than 10 moles, while magnesium perchlorate reduced it to 7½ moles in 13 days. The last drying agent was found to absorb some moisture from samples already dried to constant weight over calcium oxide. The hydrate appeared to be composed entirely of clusters of hexagonal

plates. These observations are in general agreement with previous work published in 1929.

When tricalcium aluminate or its hydrates are treated hydrothermally under conditions favouring hydrolysis, decomposition may occur, with the appearance of birefringent crystals. At the lower temperatures this anisotropic material has a refractive index of approximately 1·58, and below 150 deg. C. prolonged treatment in saturated steam (removal of lime by bleaching being excluded) results in recombination to give the isometric hexahydrate of tricalcium aluminate, which is therefore the stable product in this temperature range. As the temperature of the hydrothermal treatment is raised, the permanent segregation of birefringent crystalline phases is favoured, although the main product after prolonged treatment at temperatures below 250 deg. C. is still the hexahydrate. Treatment at temperatures of 205 to 350 deg. C. gives a product containing crystals of a calcium hydroaluminate in the form of rectangular prismatic plates with a lime-alumina ratio of less than 1·5, as well as crystals of calcium hydroxide but no free hydrated alumina. Two of the refractive indexes of the crystalline hydroaluminate are close to 1·627.

The low-limed hydroaluminate of refractive index 1·627 is also produced on treatment of a 3 : 1 molar mixture of hydrated lime and hydrated alumina in steam at 350 deg. C. It is therefore a stable product under these conditions. It thus appears probable that under conditions favouring hydrolysis at least one and possibly two birefringent hydroaluminates may be formed, one at temperatures below approximately 200 deg. C. having a mean refractive index of 1·58 and one at higher temperatures with a refractive index of 1·627.

A greater proportion of the low-limed hydroaluminate of refractive index 1·627 is formed on hydrothermal treatment of the hexagonal hydrate of tricalcium aluminate than when the anhydrous aluminate is used. The autoclaving of the anhydrous aluminate at 350 deg. C. for periods up to 14 days produced a mixture composed mainly of the rectangular plates and calcium hydroxide, although some crystals of the hexahydrate were always present. When the hexagonal hydrate was similarly treated the product appeared to be composed entirely of the rectangular plates and calcium hydroxide and the presence of the hexahydrate was not detected.

The difference in the behaviour of the anhydrous aluminate and its hexagonal hydrate on autoclaving is probably due to the fact that the autoclave must be initially heated and finally cooled through the temperature range in which the hexahydrate of tricalcium aluminate is the most stable product. In this range the anhydrous aluminate is rapidly converted to the cubic hexahydrate, while there is probably no corresponding rapid transformation from the hexagonal to the cubic hydrate. It would appear from the experimental results that, when once formed, the hexahydrate of tricalcium aluminate is capable of existing at 350 deg. C. in steam approaching saturation, and that the hydrolysis of this hydroaluminate, with separation of crystalline calcium hydroxide, possibly occurs only in the presence of the liquid phase.

The experimental data are of interest in connection with the steam-curing of precast Portland cement concrete products for the purpose of increasing strength or the resistance to the action of sulphate waters. Conditions favouring hydrolysis are probably always present, and if high temperatures are used the birefringent hydroaluminates would be formed as well as the hexahydrate of tricalcium aluminate. The temperature required for the production of the former depends on the form in which the aluminate is present, and would thus probably vary with the age of the concrete at the time of treatment.

New Method of Kiln Erection.

IN the erection of a rotary kiln in sections 98-ft. long and weighing 100 tons, the Aluminium Company of America devised a scissors-leg support and carriage (Fig. 1) that provided for lateral movement of each kiln across concrete supporting piers and at the same time provided a simple means of lowering the shell into its position. The scheme also provides for longitudinal movement of the kiln after it is aligned for welding.

The kilns, 250 ft. long, lie on a slope of ½ in. per foot and are supported at four points by cast-steel riding rings of 12 ft. 6 in. outside diameter on piers varying from 17 ft. to 25 ft. above ground level. It is usual to complete the piers and install the rollers before setting the kilns.

The two sets of "scissors-legs" that support the ends of the kiln section terminate at ground level in flanged-wheel trucks. These move on railway rails laid at right angles to the kiln centre line. As the base of such a triangle is shortened, the upper pivot point will raise. Conversely, it will lower if the base length is increased. In the mechanism the kiln shell is the upper pivot point of the triangle and the two bottom corners are the lower ends of the scissors-legs. The bottom corners rest on the trucks, and the distance between them can be varied as required by a system of sheaves and wire rope. Power is supplied by a single drum hoist turned by a reversible air-motor through a speed reducer.

Articulation at the two bottom corners of the triangle is obtained by terminating the ends of the scissors-legs with cast-steel balls which rest in sockets on the movable trucks. Articulation at the upper end of the scissors-legs, where the kiln rests and the assembly pivots, is obtained by terminating the upper end of the legs in cradles that fit the outside of the kiln shell and permit rotation with the shell as the centre. One scissors-leg has two cradles spaced 6 ft. apart; the other leg has a single cradle placed midway between the two cradles of the opposite leg. The face of the single cradle is greased and slides around the shell as the latter is raised or lowered. The upper ends of the scissors-legs are not joined, but maintain their alignment because the kiln acts as a trunnion.

The scissors-legs are made of 6 in. steel pipes with the ends trimmed so that they may be welded together into a 6 in. circle to which a steel ball is welded to form the bottom. The cradle ends of the scissors-legs are cut on a mitre and

welded to one flange of a 12 in. beam that has a wood cradle bolted to the opposite side.

Cross tying or bracing between the carriages and the tops of the opposite scissors-legs is not possible because of the high piers. Consequently, the spread of one of the scissors-legs assemblies to 6 ft. between the cradles is an important part of the moving device, as longitudinal stability of the structure depends on this and the beam stiffness of the kiln shell. There is, however, sufficient flexibility to permit an endwise movement of 6 in. to either side of the neutral position, thus making it possible to pull the ends of adjacent kiln sections together in preparation for welding.

Fig. 1.—Method of Erecting a Rotary Kiln.

Each scissors-leg assembly has equal length pipe members, a 2 in. wedge being placed under the "uphill" cradle of the two-cradle unit to allow for the $\frac{1}{2}$ in. per foot slope of the kiln. This keeps the assembly in a vertical plane and reduces the tendency to tip endwise that otherwise would occur. Because of the slope of the kiln and the fact that supporting tracks are all at ground level, sets of scissors-legs are provided for use at each end and each joint of the kiln.

Each kiln is raised to near its final elevation by means other than the scissors-legs, as the angle at which it would be necessary to start the lift makes the power required almost infinite.

A New Cement Factory.

WHAT is claimed to be the world's latest cement plant is now in operation at Northampton, Pennsylvania. It has been built for the Universal Atlas Cement Co., and is fully described by Mr. N. C. Rockwood in "Rock Products" for November, 1943, from whose article the following notes are taken. A view of the plant is shown in Fig. 1 and a plan in Fig. 2.

The cement rock in the quarry varies in analysis from 68 to 76 per cent. $CaCO_3$, with occasional bands of mixtures of fairly pure calcite and quartz. The silica and alumina are in the form of silicates, very hard to separate, and the silica : alumina ratio was too low for low-heat or for sulphate-resisting Portland cements. Since it is not feasible to separate the silica from the alumina in the flotation rejects, the silica lost with rejects is replaced by ground local sand. Provision is made for adding iron oxide when the specifications require this in place of some of the alumina, as for low-heat cement. By processing a part of the

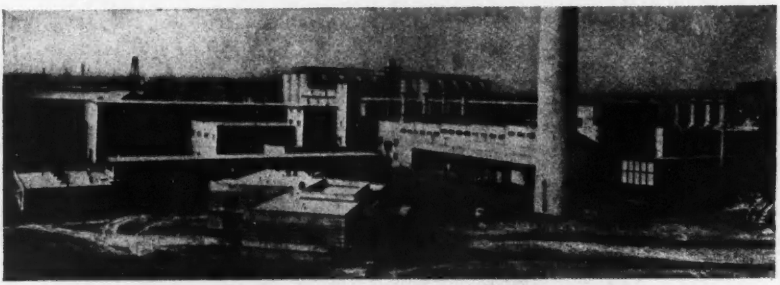


Fig. 1.—New Cement Factory at Northampton, U.S.A.

normal quarry rock it is possible to get limestone concentrates with 80 to 86 per cent. $CaCO_3$.

Crushing.

The primary crusher is a 36 in. by 60 in. roll crusher (a single slugger roll) driven by a 300 h.p. 440 volt A.C. motor at 48 r.p.m. The product is minus 8 in. It is conveyed to a separate building housing the secondary crushing machinery by a 36 in. belt conveyor at an incline of 18 deg.

The first step is to screen out, on two double-deck 5 ft. by 10 ft. vibrating screens, all the minus $\frac{3}{4}$ in. stone, which is the finished product. The top decks of the screens are 2 in. square mesh and the lower decks $\frac{3}{4}$ in. mesh; the sole object of the top deck is to protect the $\frac{3}{4}$ in. screen and increase its efficiency by removing the plus 2 in. stone. Rejects of both screens' surface go to a reversible hammer-mill at the ground-floor level. The minus $\frac{3}{4}$ in. product is chuted from the screens to a 30 in. conveyor belt, hooded with a dust-collector intake. The screens are enclosed and connected to the same dust collector. The dust collected is fed to the conveyor belt ahead of the $\frac{3}{4}$ in. stone, to protect the feed chute and the belt from excessive abrasion.

The reversible hammer-mill has a capacity of 425 tons per hour and is driven by a 600 h.p. 440 volt A.C. motor at 720 r.p.m. Like all the major units in the plant, the hammer-mill may be stopped with a push button, but not started again except from the main control board and in proper sequence through interlocking switches. Near the feed end of the 30 in. conveyor carrying the ¾ in. stone and dust is a weight-recording machine. The 30 in. belt discharges through a movable tripper to any of several compartments in a storage building 624 ft. long by 100 ft. wide, equipped with two travelling cranes, one for stone and the other for clinker and gypsum. The stone fed to the mills is all minus ¾ in. and possibly 50 per cent. of it is minus ⅜ in. This is finer than the average raw materials fed to preliminary ball mills, and accounts for some of the increased efficiency in the raw grinding department.

The raw material grinding plant comprises two rows of feed bins, feeders, short primary ball mills, rake classifiers close-circuited with these to return the oversize and pass the overflow to bowl classifiers, which float off the finished grind and feed the sands to the secondary ball mill. The secondary mill product returns to the bowl classifier, for the same circuit. The water comes mostly from the slurry thickeners, and is thus retained in a closed circuit which encompasses the entire processing operation. Theoretically no raw material, including also most of the reagents used in the flotation plant, are lost from the system. An entirely separate and smaller raw grinding and classification unit is used to grind sand or iron ore, providing a sand slurry or an iron ore slurry which can be combined with any of the limestone slurries in any proportions. Another innovation is the use of sand wheels to elevate the bowl classifier sands to feed the finish ball mills by gravity. The white cement raw materials are ground in a separate building but with grinding and classifying units of the same character.

Clinker Grinding.

The raw material and clinker mills are in the same building. The finish mills have two compartments, and have end discharge. They are preceded by short ball mills as preliminary grinders. The product of the preliminary ball mill is fed direct to the two-compartment mill and the discharge is elevated to air separators, the oversize being returned for the complete circuit through the mill and separator.

The finish mill controls are on switchboards between the preliminary and finish mills. Connected with each ball and compartment mill is a switchboard for controlling an electric welding machine. By means of a cam-operated switch and a rheostat an "artificial" alternating current is created from the low voltage, high amperage, direct current, with a very slow cycle (some 60 times longer than the normal cycle for the 60-cycle synchronous motors driving the mills). This slow cycle current is sent through the stators of the synchronous motors at about the same amperage they normally operate on, which permits turning the motors very slowly so that the mill manhole for discharging the ball load may be brought into position in minutes as compared with hours by other methods. This device is shown in Fig. 3.

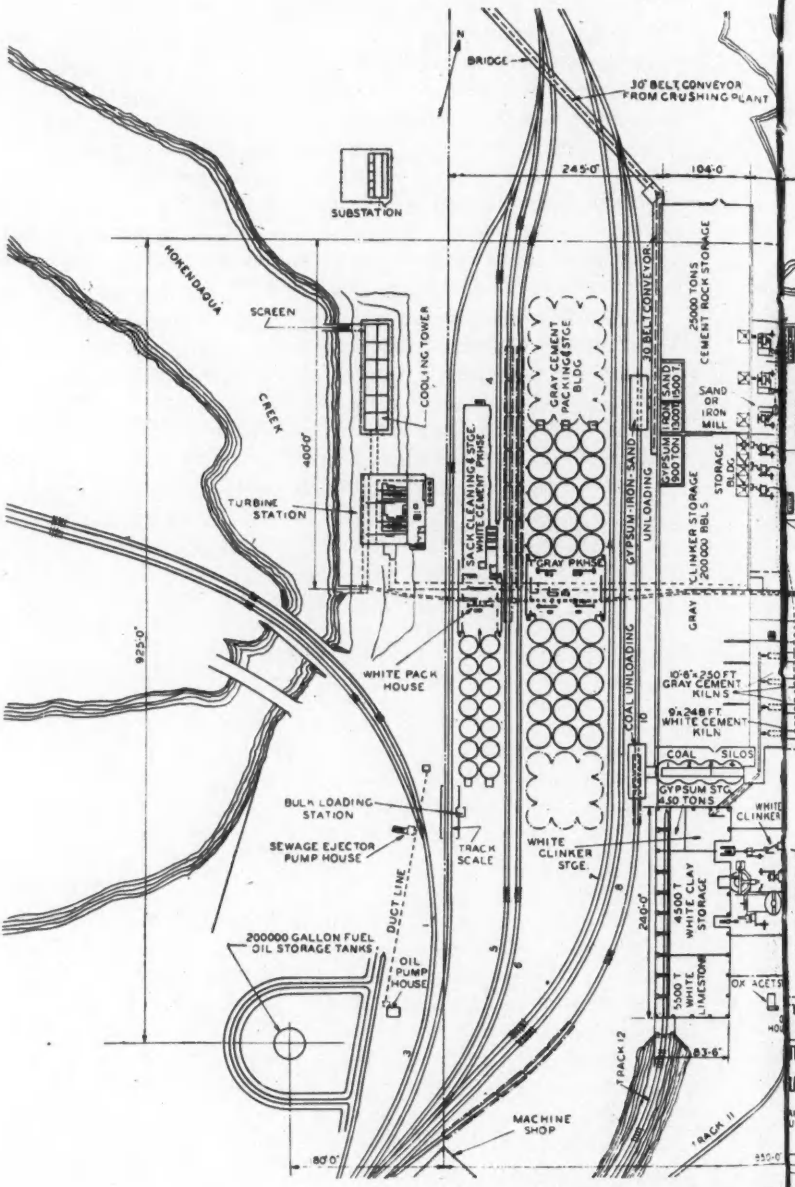
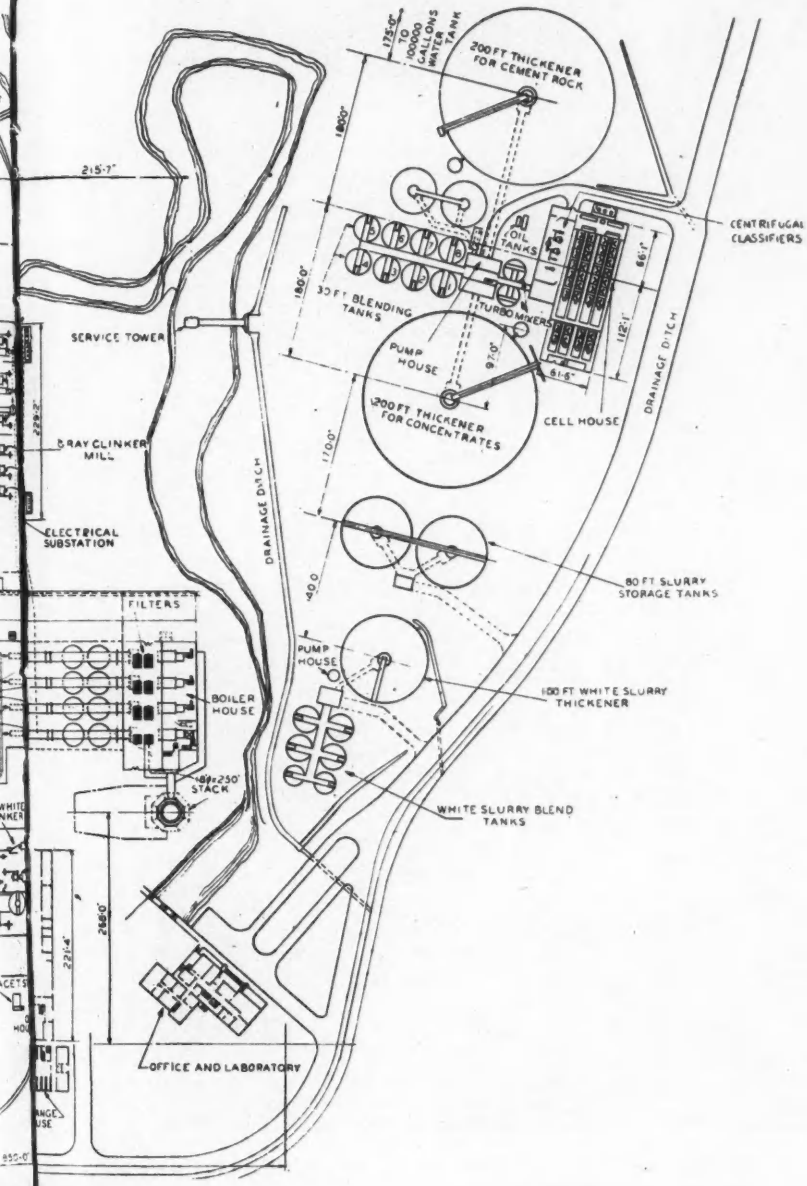


Fig. 2.—Plan of New Cement Plant



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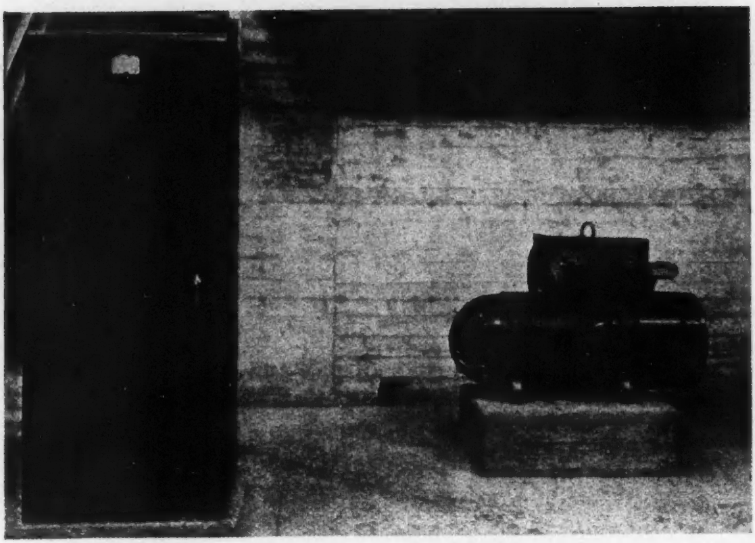

Fig. 3.—Device for Turning Motors Slowly.

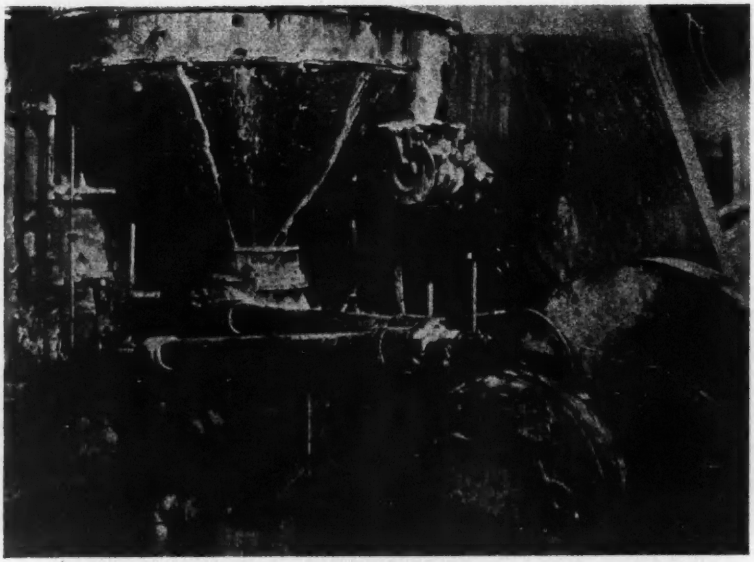

Fig. 4.—Slurry Pump of the Type Used for Pumping Concrete in Construction Work.

The Kilns.

Slurry from the kiln storage tanks is pumped to concrete tanks under the feed end of each kiln, from which it is pumped to the constant level basin which feeds the disc filters. The overflow of the constant level basin returns by gravity to the kiln feed tanks.

Two rotating-disc type vacuum filters are provided for each kiln. These have two variable vacuums, each with an indicator. One vacuum is designed to control the depth of the cake and the other the dryness or amount of dewatering of the cake previously picked up. Each filter unit consists of nine discs 8 ft. 10 in. in diameter, with a total filtering area of 936 sq. ft. The filters are designed to reduce the moisture content of the slurry from 36 to about 23 per cent. Vacuum

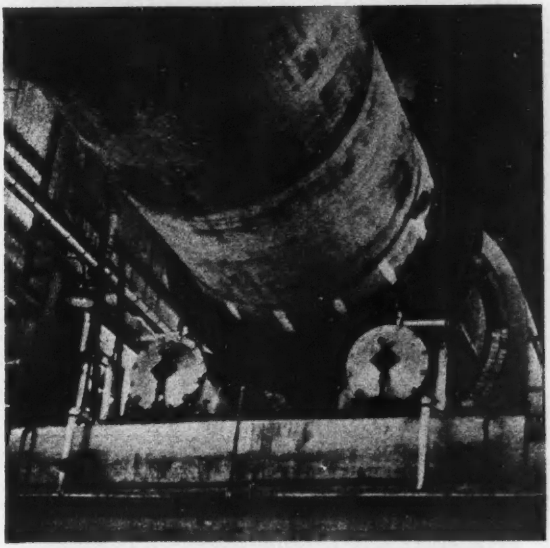

Fig. 5.—Showing Wedges for Aligning Kiln.

for the filters is supplied by rotary pumps. The filters are also provided with variable speed control. The filter cake drops into hoppers feeding pug-mill type conveyors, which push it into the feed hoppers over a standard type of pump as used for pumping concrete in construction work (Fig. 4). This method of feeding slurry cake to the kiln has the advantage that the feed pipe, packed around with fire clay, gives an air-tight connection with the kiln, and the construction and operation of the pump is such that no gases from the kiln can escape through it. The dust collected under the economisers and waste-heat boilers is fed to the pug-mill mixers ahead of the filter-cake pumps by screw conveyors and an elevator to a screw conveyor above the floor of the filter room, which distributes the dust to the pug-mill mixers in any amount desired.

There are four kilns, one 9 ft. diameter and 248 ft. long, and the other three 10 ft. 6 in. diameter and 250 ft. long. These kilns have all-welded shells with stiffening rings every 20 ft., and each is carried on four box-type rings riding on solid forged rolls, which have water-cooled bronze bearings and flood-oil lubrication. The kiln drives are 125 h.p. adjustable-speed D.C. motors. The kiln shells have wedges inside the riding rings to facilitate alignment (Fig. 5). The kilns also have manholes about 75 ft. from the discharge end to facilitate handling the lining brick.

Unit coal pulverisers take hot air from the tops of the kiln hoods for drying the coal and primary combustion air and air from the hottest part of the clinker cooler for secondary air.

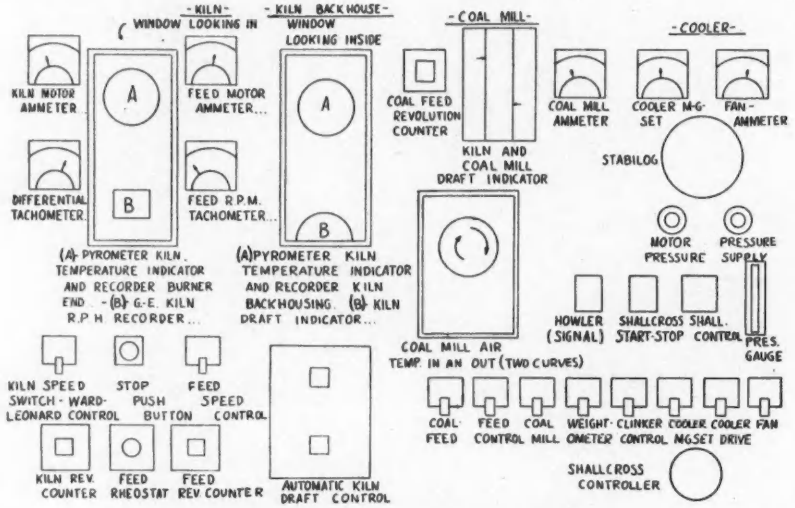

Fig. 6.—Diagram of Kiln Control Switchboard.

The clinker coolers are of the enclosed box conveyor type, one using a reciprocating grate mechanism and three shaker-grates. Elevators take the clinker to the storage building.

The control board diagram (Fig. 6) shows that there is no attempt at overall "automatic" control. The kiln-speed control and the kiln-feed speed control can be changed at will and the differential tachometer shows the difference in speeds; they can be synchronised or not. The kiln draught control is automatic. The "Stabilog" and the instrument automatically control the clinker cooler by keeping a constant difference in pressure above and below the clinker bed on the shaker grate. Thus, if the bed becomes too thick the difference will be too great and increasing the speed of the cooler will tend to spread the bed thinner, or vice versa.

Packing.

In the main pack house (for ordinary Portland cement) is a master switchboard which shows all the cement pump lines and where the cement is flowing at the moment, including white cement. This switch and control board (Fig. 7) is in front of the pack-house office, which is a glass enclosure facing the switchboard. Lights on the board show the pump lines and silos in use, and the packing machines and silos to which the cement is going.

There are two groups of fifteen reinforced concrete cylindrical bins in three rows with eight interstice bins (30 silos in all) with a storage capacity of over

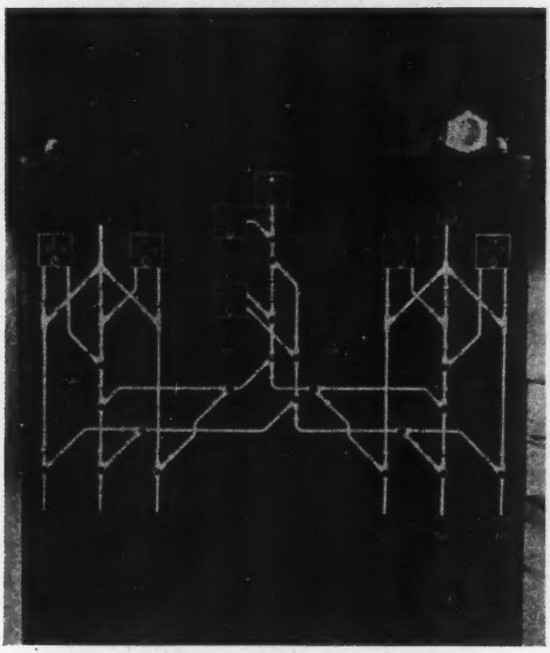

Fig. 7.—Control Board for Cement Pumps.

75,000 tons. Dividing the two 15-silo groups is the packing plant with four dustless bag packers. The packing machine hopper bins are fed by movable cement pumps which travel in galleries under the rows of bins, with the air compressors in rows under the pack house at right angles to the pump galleries.

The packing plant for white cement is separated from the other packing plant by two railway tracks, but the overhead gallery is continuous through both pack houses. Bulk cement may be loaded direct from any of the rows of outside silos through spouts from the bins, the flow of cement being facilitated by compressed air piped in near the spout intakes. In addition, a separate

weighing house is provided where trucks to be loaded with bulk cement stand on a track scale and the load of cement is pumped into them, with an automatic cut-off when the desired weight is reached. This apparently is a new cement plant feature.

X-Ray Patterns of Hydrated Calcium Silicates.

IN the year 1938 a report on the hydrothermal synthesis of hydrated calcium silicates was prepared by Messrs. E. P. Flint, H. F. McMurdie, and L. S. Wells, and published as Research Paper No. 1147 by the U.S. National Bureau of Standards. Since then, because of the occurrence of hydrated calcium silicates in the hydration products of Portland cement, boiler scale, etc., the patterns have been remade on more modern equipment, and the data obtained are given in Research Paper No. 1560 by Messrs. H. F. McMurdie and E. P. Flint.

Of the fifteen calcium silicate hydrates considered seven occur as natural minerals, and these natural minerals were used to prepare the patterns. The other eight compounds were formed as described in the paper published in 1938. *Table* 1 gives the source of the minerals and the starting material and subsequent treatment of the synthetic preparations. The experiment numbers from the previous paper are also given and in that paper a complete discussion of the

TABLE 1.—ORIGIN OF MATERIALS.

A. MINERALS

Mineral	Composition	Place of origin
Okenite	$CaO.2SiO_2.2H_2O$	Disco Island, Greenland.
Gyrolite	$2CaO.3SiO_2.2H_2O$	Benkoelen, Sumatra, Netherlands East Indies.
Xonotlite	$5CaO.5SiO_2.H_2O$	Isle Royale, Mich.
Crestmoreite	$2CaO.2SiO_2.3H_2O$	Crestmore, Riverside County, Calif.
Foshagite	$5CaO.3SiO_2.3H_2O$	Do.
Afwillite	$3CaO.2SiO_2.3H_2O$	Dutoitspan Mine, Kimberley, South Africa.
Hillebrandite	$2CaO.SiO_2.H_2O$	Velardena District, Durango, Mexico.

B. SYNTHETIC PREPARATIONS

Composition	Method of preparation				Experiment No.[a]
	Starting material	Temperature	Pressure	Time	
		°C	atm		
$4CaO.5SiO_2.5H_2O$	0.80CaO. SiO_2 aq	225	25	14 days	20
$CaO.SiO_2.H_2O$	CaO. SiO_2 aq	150	5	60 days	25
$6CaO.4SiO_2.3H_2O$	$\beta 2CaO.SiO_2$	25	1	10 years [b]	61
$2CaO.SiO_2.H_2O$	2CaO. SiO_2 aq	225	25	44 days	63
$2CA.OSiO_2.H_2O$ [c]	$\beta 2CaO.SiO_2$	250	39	15 days	65
$10CaO.5SiO_2.6H_2O$	$\beta 2CaO.SiO_2$	200	15	3 days	66
$6CaO.3SiO_2.2H_2O$	$10CaO.5SiO_2.6H_2O$	450	400	7 days	70
$3CaO.SiO_2.2H_2O$	$3CaO.SiO_2$	250	39	12 days	75

[a] Experiment numbers from previous paper (J. Research NBS 21, 617 (1938) RP1147).
[b] Later treated at 175° C in bomb for 41 days.
[c] Index of refraction = 1.60.
[d] Index of refraction = 1.64.

TABLE 2.—DIFFRACTION DATA.

Estimated [1] intensity	d
Okenite ($CaO.2SiO_2.2H_2O$)	
	A
VS	8.91
W	7.67
VW	6.63
VW	4.22
M	3.59
M	3.09
M	2.99
S	2.96
S	2.83
VW	2.73
VW	2.57
VW	2.41
W	2.16
VW	1.897
M	1.823
Gyrolite ($2CaO.3SiO_2.H_2O$)	
M	9.6
W	7.9
W	6.4
W	4.68
S	4.24
M	3.84
W	3.54
VS	3.36
M	3.15
VW	3.02
VW	2.92
S	2.85
M	2.65
VW	2.58
VW	2.52
W	2.45
W	2.29
M	2.25
W	2.12
W	2.095
VW	2.060
VW	1.990
VW	1.940
S	1.884
M	1.813
Xonotlite ($5CaO.5SiO_2.H_2O$)	
M	7.10
S	4.22
VS	3.61
S	3.24
S	3.07
M	2.82
M	2.68
VW	2.62
M	2.49
W	2.41
W	2.25
S	2.03
S	1.940
M	1.826
W	1.748
M	1.705
W	1.679
Crestmoreite ($2CaO.2SiO_2.3H_2O$)	
	A
M	14.9
S	10.4
W	5.5
W	4.9
VW	4.14
W	3.74
M	3.50
VW	3.29
VS	3.09
S	2.95
VS	2.84
M	2.74
W	2.66
VW	2.34
W	2.26
VW	2.18
W	2.05
M	1.959
M	1.861
M	1.819
VW	1.792
W	1.773
W	1.735
Foshagite ($5CaO.3SiO_2.3H_2O$)	
M	9.7
M	8.0
M	5.67
M	5.06
M	3.42
S	3.36
M	3.24
W	3.09
S	2.93
S	2.81
M	2.72
W	2.48
VS	2.31
S	2.16
W	2.11
W	2.075
W	2.040
W	1.950
VW	1.910
W	1.827
W	1.776
S	1.745
Afwillite ($3CaO.2SiO_2.3H_2O$)	
S	6.5
M	5.06
W	4.68
W	4.18
VW	3.76
VS	3.17
VW	3.05
VS	2.85
S	2.74
W	2.66
W	2.59
VW	2.44
M	2.36
VW	2.33
VW	2.275
M	2.159
Afwillite $3CaO.2SiO_2.3H_2O$—Con.	
VW	2.065
W	2.026
W	1.988
M	1.955
W	1.924
W	1.868
M	1.858
M	1.782
VW	1.735
W	1.705
W	1.679
W	1.629
M	1.606
M	1.596
W	1.564
Hillebrandite ($2CaO.SiO_2.H_2O$)	
S	12.6
M	4.77
VW	4.05
VW	3.52
M	3.34
M	3.01
VS	2.92
VW	2.83
VW	2.75
VW	2.68
VW	2.62
VW	2.45
M	2.373
M	2.247
W	2.056
M	1.963
W	1.928
M	1.864
M	1.812
W	1.747
$4CaO.5SiO_2.5H_2O$	
S	4.22
W	3.76
M	3.14
S	3.05
W	2.85
VW	2.67
W	2.52
W	2.30
M	2.105
M	1.924
W	1.877
M	1.841
$CaO.SiO_2.H_2O$	
VW	6.13
W	4.32
W	4.24
VW	3.80
W	3.58
M	3.21
VS	3.01
$CaO.SiO_2.H_2O$—Continued	
	A
M	2.78
M	2.50
S	2.23
VW	2.116
W	2.013
S	1.893
VW	1.868
VW	1.808
M	1.772
VW	1.632
W	1.601
$6CaO.4SiO_2.3H_2O$	
M	4.30
W	3.68
W	3.45
VW	3.39
M	3.22
VS	3.10
W	2.98
VW	2.94
W	2.86
W	2.73
W	2.64
W	2.58
S	2.253
S	2.066
W	2.034
VW	1.987
M	1.943
VW	1.897
W	1.833
W	1.792
W	1.756
S	1.699
$2CaO.SiO_2.H_2O$ ($n=1.60$)	
W	4.83
M	4.26
W	3.55
W	3.38
W	3.28
S	3.05
VS	2.93
VW	2.42
W	2.40
W	2.24
W	2.07
M	1.963
M	1.875
M	1.819
W	1.637
$2CaO.SiO_2.H_2O$ ($n=1.64$)	
W	4.22
VW	3.82
VS	3.04
M	2.84

[1] S, strong; M, medium; W, weak; V, very; B, broad.

TABLE 2.—DIFFRACTION DATA (*continued*).

Estimated ¹ intensity	d
2CaO.SiO₂.H₂O (n=1.64)—Con.	
	A
S	2.70
M	2.47
W	2.35
S	1.897
W	1.850
M	1.799
W	1.732
M	1.656
W	1.540
M	1.264
W	1.170
W	1.156
10CaO.5SiO₂.6H₂O	
VW	5.33
S	4.18
W	3.91
M	3.53
S	3.27
VW	3.05
M	2.89
M	2.80
W	2.72

Estimated ¹ intensity	d
10CaO.5SiO₂.6H₂O —Continued	
	A
W	2.66
W	2.59
VW	2.51
S	2.41
VW	2.32
W	2.24
W	2.15
W-B	2.05
VW	1.98
W	1.950
M	1.915
W	1.833
S	1.780
M	1.730
M	1.706
S	1.649
6CaO.3SiO₂.2H₂O	
W	8.64
W	4.63
W	4.24
W	3.79

Estimated ¹ intensity	d
6CaO.3SiO₂.2H₂O —Continued	
	A
VW	3.39
VW	3.30
VW	3.23
S	3.06
M	2.96
S	2.85
VS	2.81
S	2.71
M	2.607
S	2.535
W	2.455
VW	2.404
VW	2.349
S	2.275
M	2.22
W	2.169
M	2.140
M	1.987
VW	1.951
VW	1.928
VW	1.901
W	1.738
M	1.705
W	1.670
M	1.634
W	1.421

Estimated ¹ intensity	d
6Ca· 3.2H₂O —Continued	
	A
W	1.406
M	1.270
3CaO.SiO₂.2H₂O	
M	8.8
M	3.32
M	3.03
VS	2.91
M	2.83
W	2.47
VW	2.17
M	2.088
VW	2.026
W	1.996
S	1.879
S	1.769
M	1.696
VW	1.667
W	1.632
M	1.573
W	1.506
W	1.438
W	1.366

methods used is presented. Some of these phases were made at the time of the previous study, others were remade, and all were examined with the petrographic microscope to assure reasonable purity. The patterns were registered with cameras of about 5·7 cm. radius, using CuKα radiation.

Table 2 gives the interplanar spacings (*d*) and estimated relative intensities for fifteen calcium silicate hydrates. These compounds all have symmetry which is orthorhombic or lower; therefore, it is all but impossible to index the reflections.